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NIC

National Ignition Campaign (NIC) Hohlraums
Part 2a: NIC plasma conditions

Presentation to
NIC Science of Ignition Webinar Tutorial Series
May 10, 2012 LLNL, Livermore, Ca

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NNSA GENERAL ATOMICS UR LLE Lawrence Livermore National Laboratory Los Alamos NATIONAL LABORATORY Sandia National Laboratories

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In “Part 2” we trace the origins of the High Flux Model (“HFM”) used to describe NIC ignition scale hohlraums

The NIC ‘09 1 MJ hohlraum energetics campaign showed very good Coupling, Drive and Symmetry

But there were inconsistencies within each category

With a better physics model, and a deeper analysis of the data, we now have:

Improved data consistency & a fuller understanding of Coupling, Drive, & Symmetry

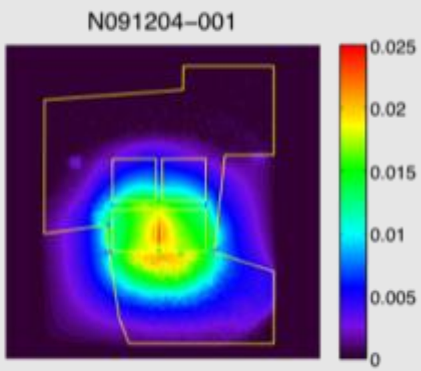
The better physics model includes:

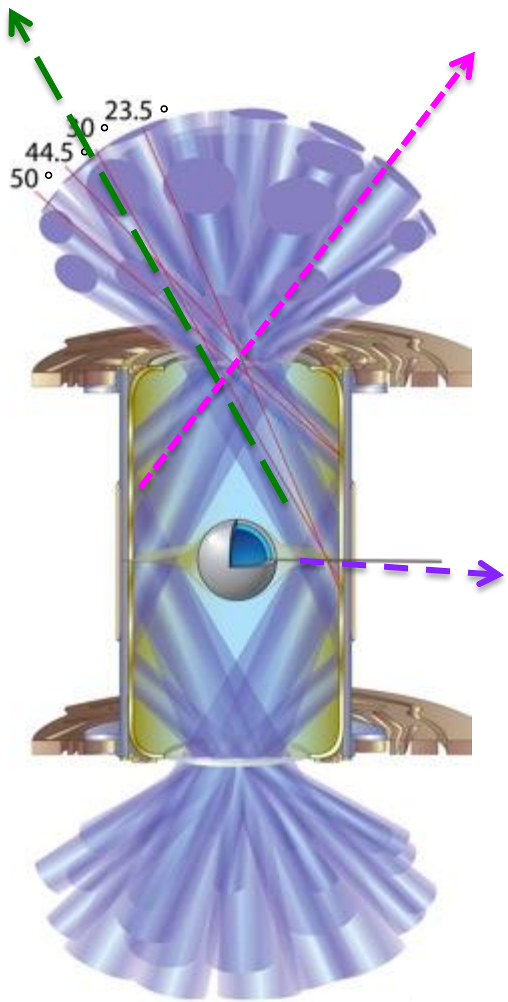
A Detailed Configuration Accounting (DCA) Atomic Physics Model
An improved electron conduction model

It resulted in an improved hohlraum shape

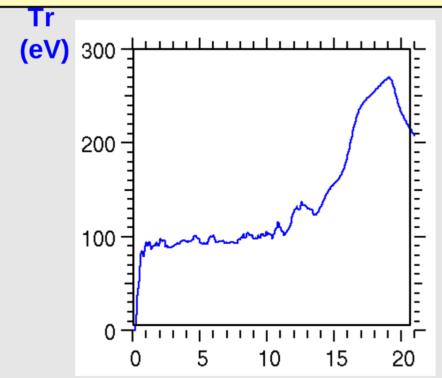
The Dec. '09 1 MJ shot provided very good Coupling, Drive, & Symmetry…

Coupling: ~ 90% of incident laser stayed inside the hohlraum

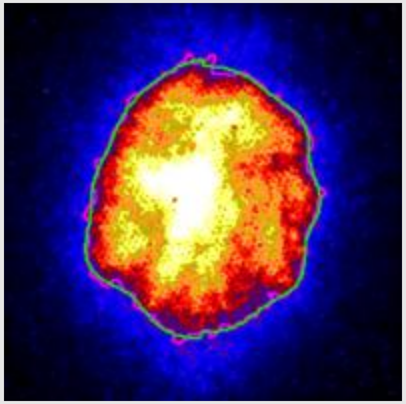




Drive: ~ 285 eV which is already quite close to that needed for ignition



Symmetry: To within ~ 10% of round, and tunable via $\Delta\lambda$



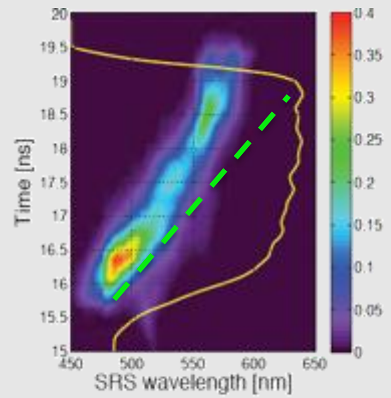
S. Glenzer et al., *Science* 327, 1228 (2010)

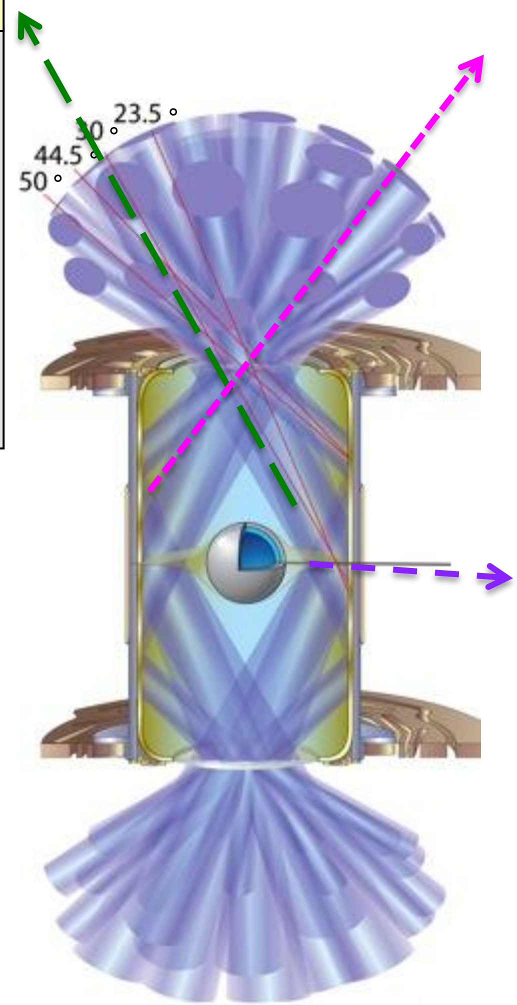
N. Meezan et. al. PoP 17, 056304 (2010

P. Michel et. al. PoP 17, 056305 (2010)

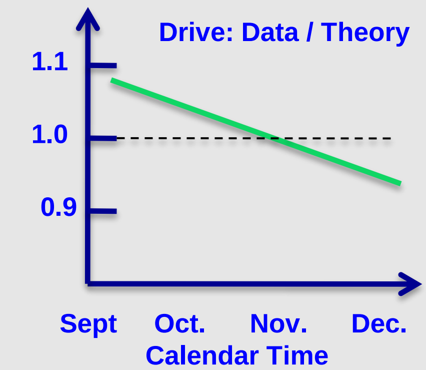
…but, there were inconsistencies within each category

Coupling: Color & level of Raman scattered light not what was expected

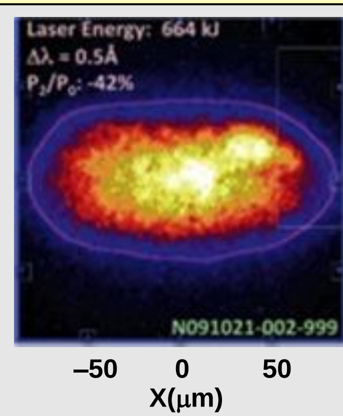




Drive: Energy accounting was off: Surplus in Sept., and a Deficit in Dec.



Symmetry: Why was the implosion pancaked *prior* to the $\Delta\lambda$ symmetry tune?



Hohlraum / capsule modeling methodology

- Use 2-D and 3-D radiation hydrodynamic codes (Lasnex, Hydra)
  - Model laser propagation, absorption, electron conduction, non-LTE x-ray production, radiation drive on capsule,…

- Step 1: Use full incident laser into hohlraum
- Step 2: Apply cross-beam transfer model with those plasma conditions
  - Set a Δn saturation parameter once
- Step 3: Re-run calculation with new (post cross-beam transfer) predicted beam balance as the incident beams

- An in-line self-consistent cross-beam transfer is being implemented to replace Steps 1-3

- Step 4: But first subtract from those incident beams the measured SRS and SBS losses.

- We've begun using a more self-consistent package that locally legislates / SRS / SBS & sends their light back through the plasma. Replaces step 4.

We deployed a hohlraum simulation model with improved physics: The High Flux Model ("HFM")

High (radiation & electron) Flux Model ("HFM"): 2 main physics improvements:

1) Better Non-LTE atomic physics (DCA)

- **100s of levels**
  - **vs. older 10 level Non-LTE XSN model**
- **Radiates more efficiently: diel. recomb. re-populates "active" levels**

2) Better treatment of electron conduction

- **Flux limited diffusion, fnvT, has a "liberal" flux limiter: f = 0.15**
  - **vs. older model's more restrictive f = 0.05**
- **Agrees with a sophisticated non-local transport model**
- **Conducts more efficiently**

A better model could make a difference on the NIF scale:

- **"Volume emission becomes more important at large scales" - L. Suter**

Key change from older model: HFM radiates and conducts energy away from the hot hohlraum plasma & makes it cooler.

Based on SRS spectra, Hinkel & Williams made the inspired guess that the plasma was cooler than expected. HFM was ready to "supply" that cooler T.

HFM does a better job than XSN / f = 0.05

2005 / 0-D: DCA High Z emissivities match more detailed models (L. Suter, S. Hansen, H. Scott et al)

Au Emissivity (TW/cc)
@ T_e= 2 KeV, ρ = 0.01 g/cc

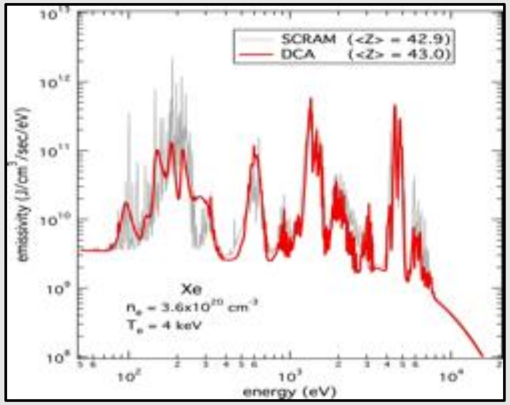
SCRAM: 7.4
DCA: 7.9
XSN: 3.1

IFSA 2009

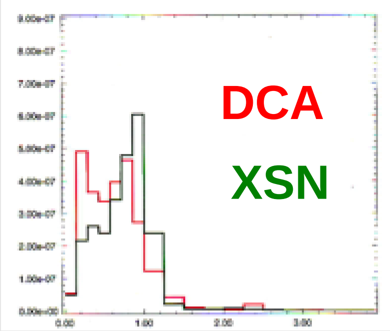
Xe Emissivity:
@ T_e= 4 KeV,
ρ = 0.002 g/cc

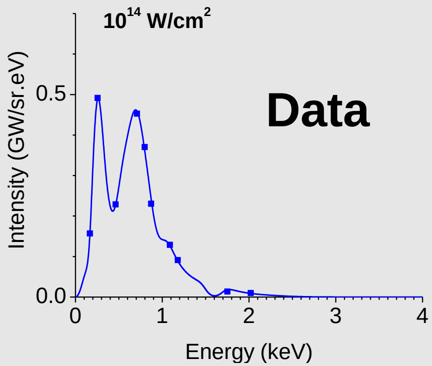
SCRAM: vs. DCA

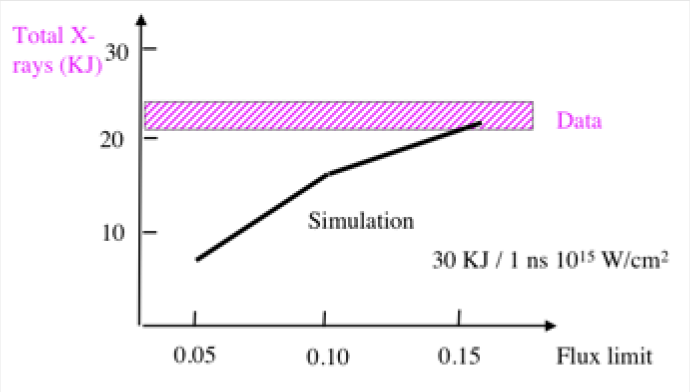
HEDP **6**, 39 (2010)



2007 / 1-D: Ω Au Sphere: HFM matched sub-keV data: (E. Dewald, M. D. Rosen, et al PoP 15 072706 (2008))
DCA ~matches shape, f=0.15 ~matches level







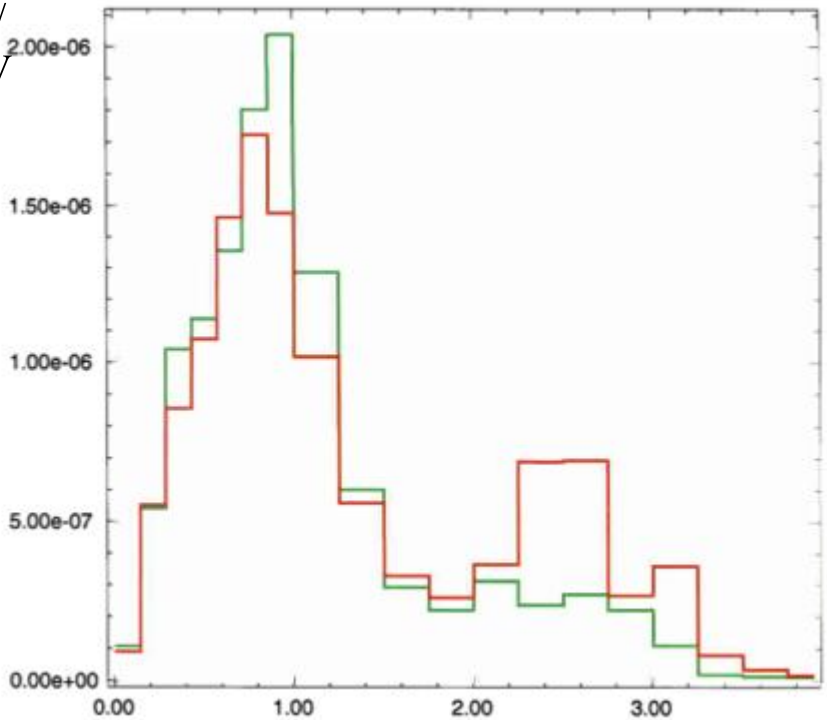
DCA agrees better with the spectral shape for Au than XSN (@ 10^{15} W/cm^2)

XSN, DCA Simulations

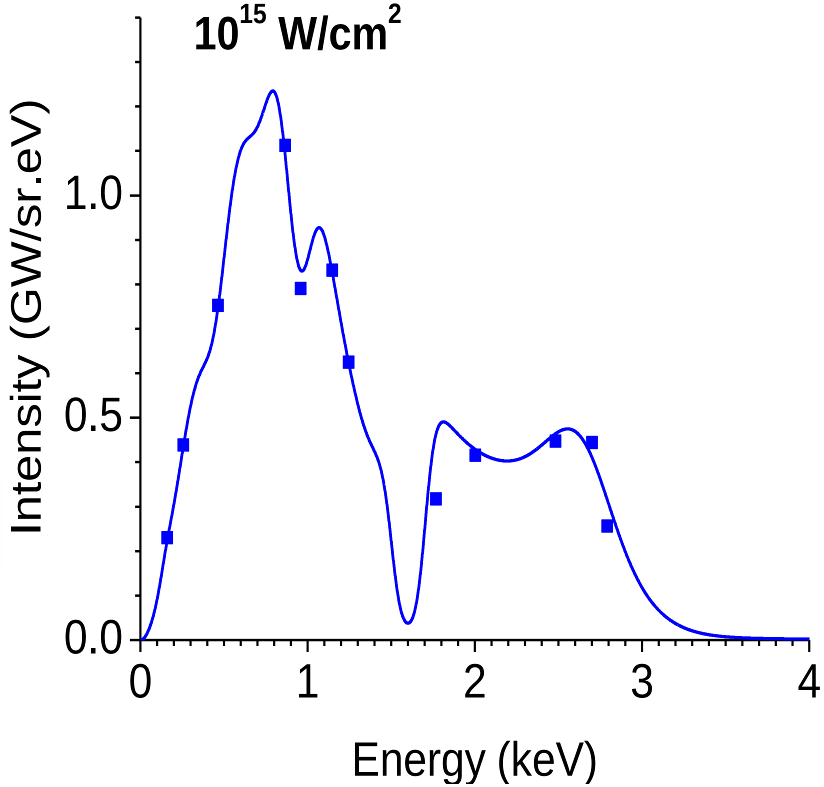
GW/
sr.eV

1.0

0.5



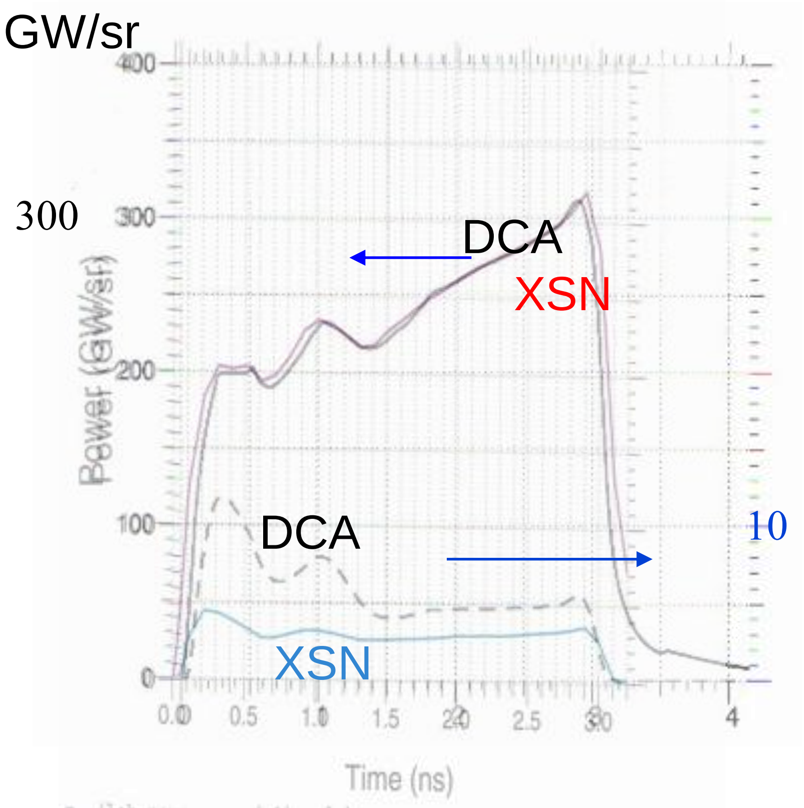
Data



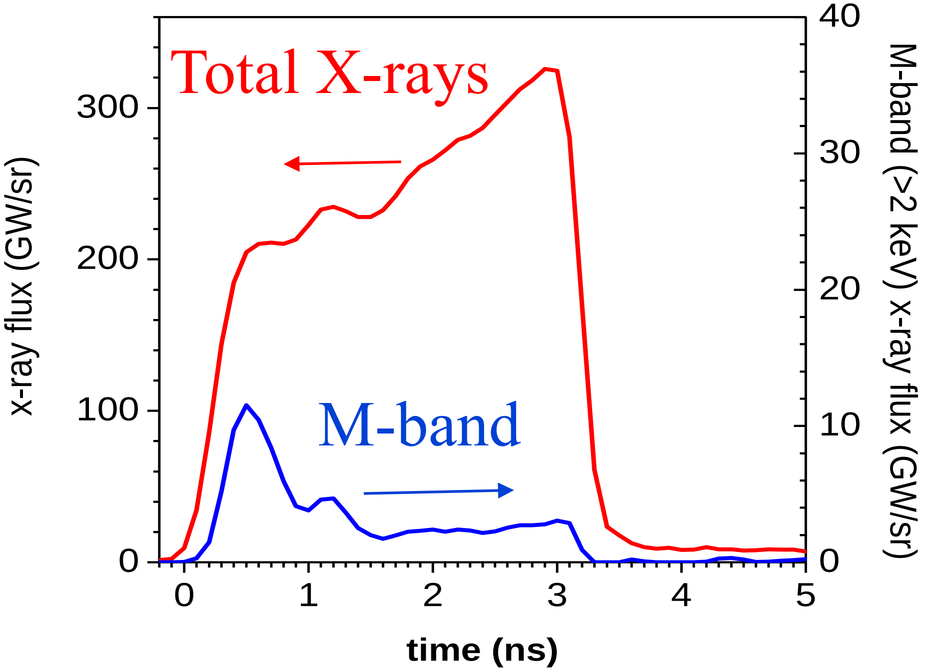
Au sphere @ 30 KJ / 1 ns 10^{15} W/cm^2 at t = 0.9 ns

DCA M-band vs. time agrees better with the data than XSN (@ 10^{14} W/cm^2)

DCA & XSN Simulations



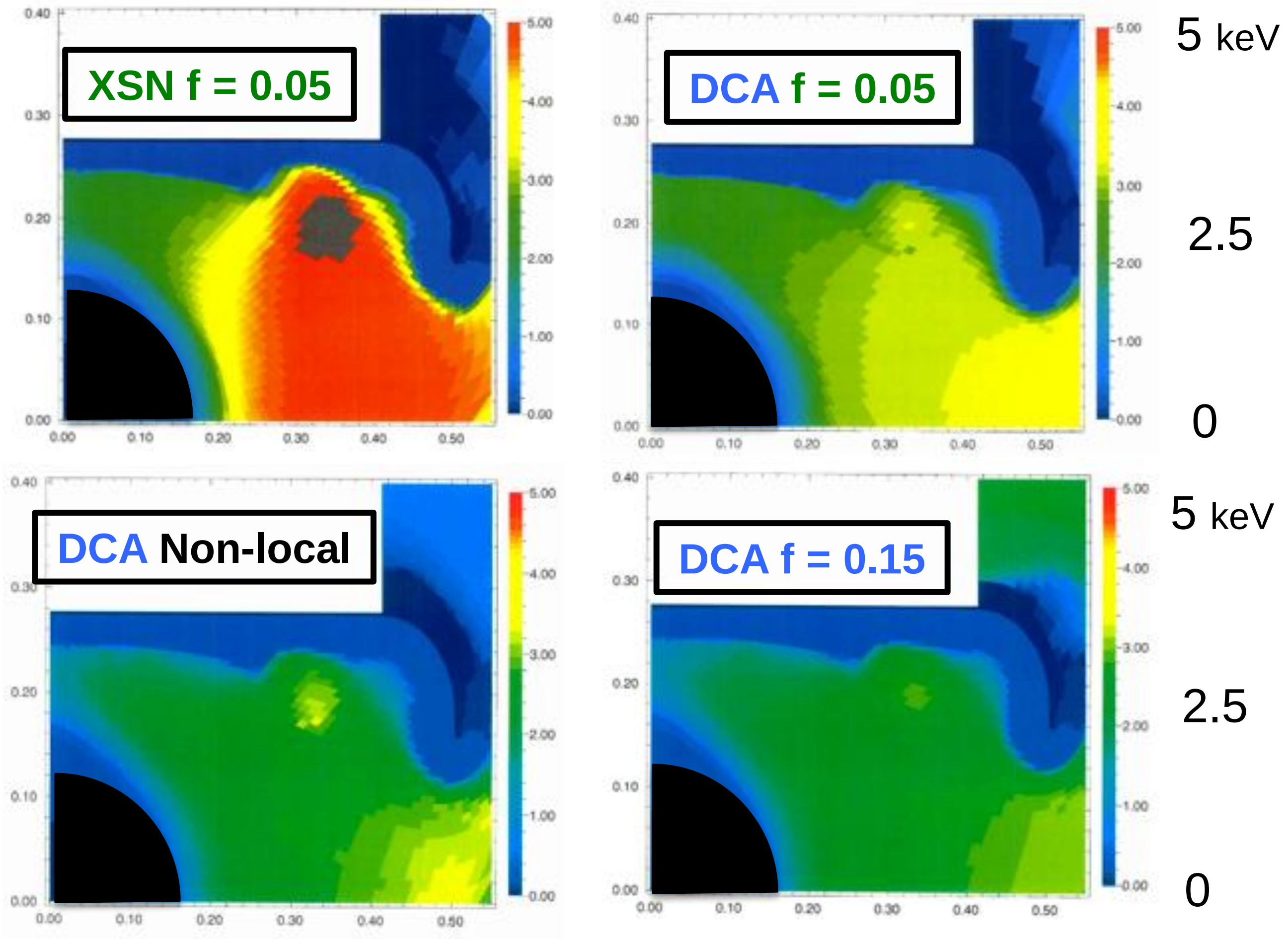
Data



Au Sphere @ 10 KJ / 3 ns 10^{14} W/cm^2

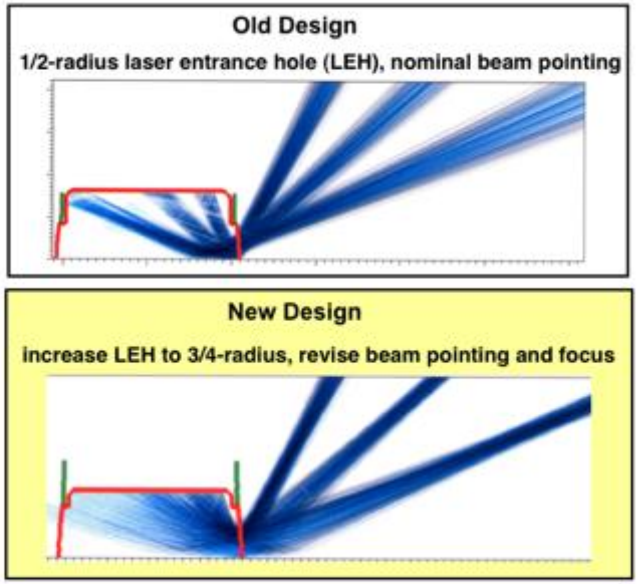
The non-local electron transport model acts like the "liberal" flux limit of f =0.15

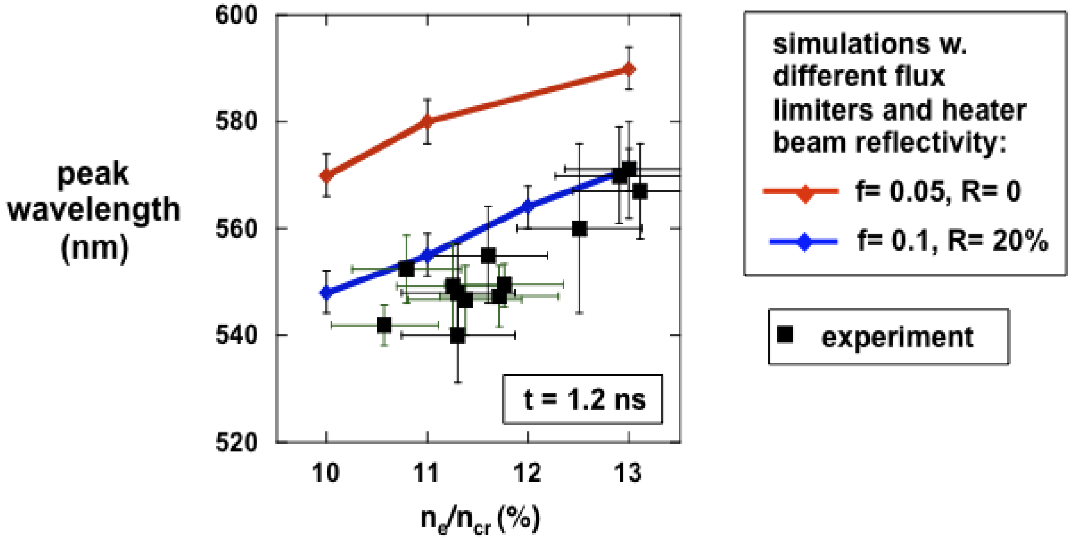
T_e (0-5 keV contours) in 1 MJ hohlraum at 18 ns (middle of main pulse)



Electron transport in hot plasma w. L<< λ_{mfp} is inherently a non-local process

On Omega, a redesign led to smoother hohlraum illumination…& a higher flux limiter !



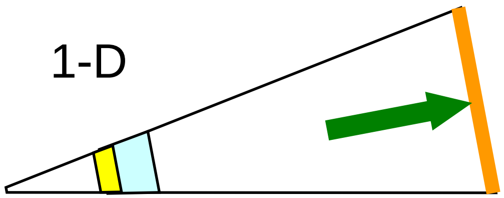


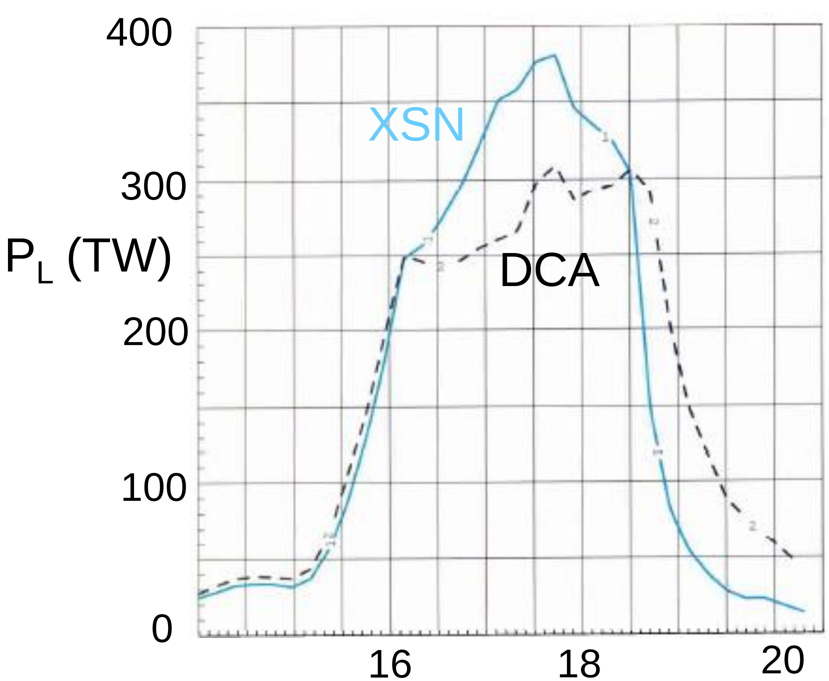
R. London APS/DPP 2008

Perhaps a “smoothed” system has a higher f, “more liberal” flux limiter,
vs.
Tight spot geometries that lead to the need for a smaller f, “tighter” flux limit.

DCA gives higher flux: But how much higher?

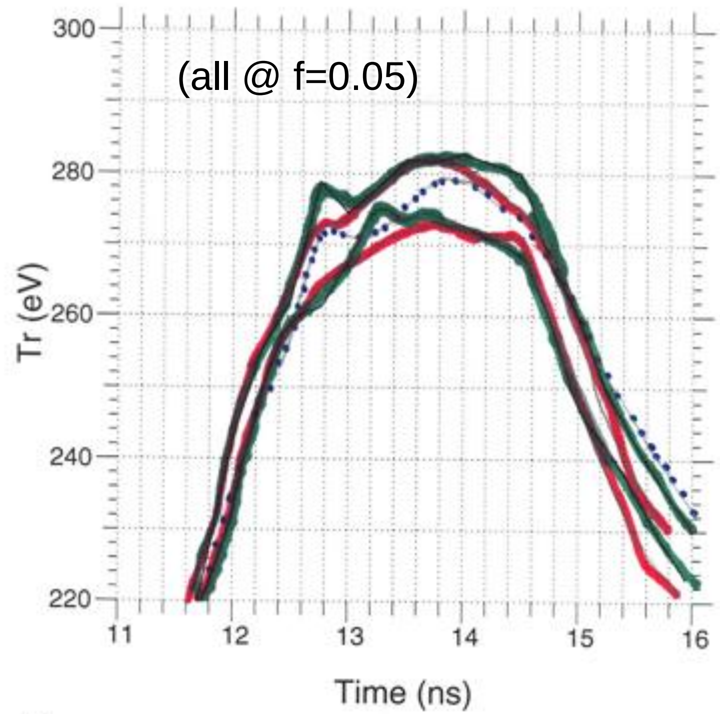
2006 / APS-DPP Suter: ~ 20% effect vs. 2008/ APS-DPP Rosen: ~ 5 % effect





Both curves give same ignition T_r(t).

Full 2-D ignition simulations



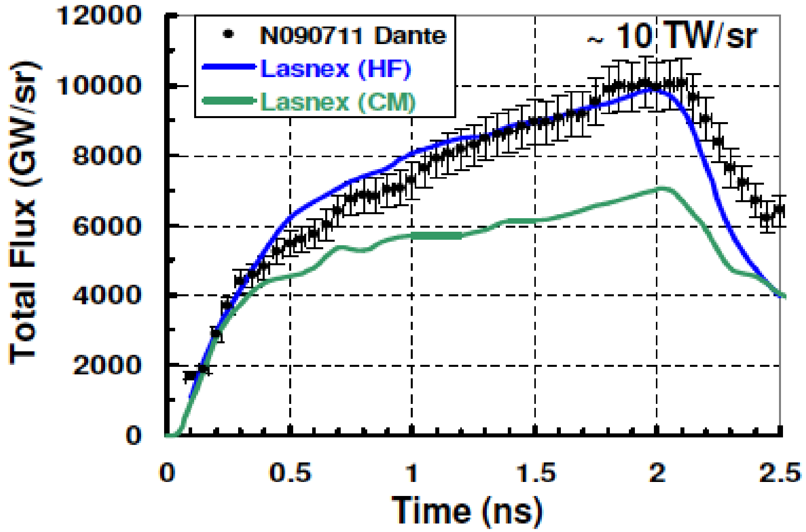
XSN: dotted line

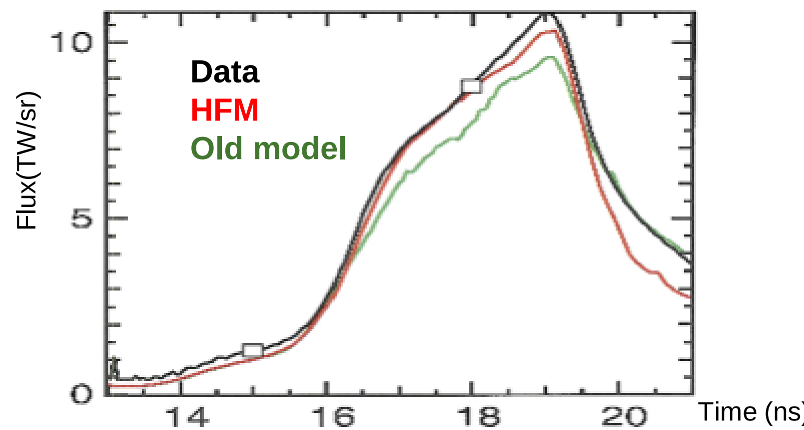
XSNLJS or DCA: full / 90%

Speculation: Both answers were ~ “correct”

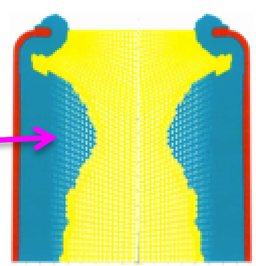
With f=0.15: Suter: ~ 30% effect vs. With f=0.15: Rosen: ~ 10 % effect

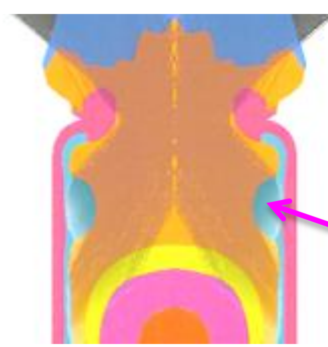
NIC Empty hohlraums	Gas-filled Ignition hohlraums
Kline, Olsen, Rosen, Callahan et al ‘09	R. Town et al ‘10





Empty hohlraums resemble Suter’s 1-D simulations : Big, ~ uniform “gold bubble” / corona dynamics





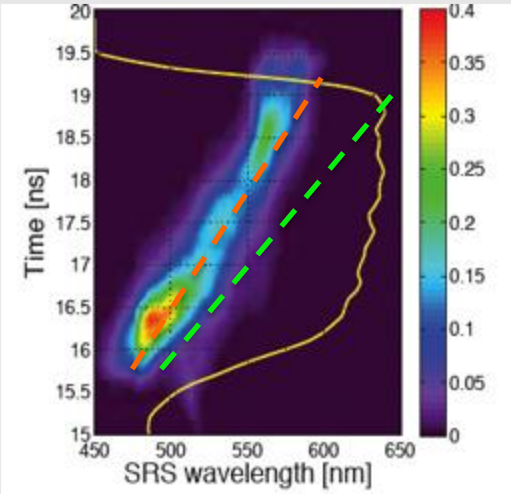
Gas-filled ignition hohlraums : Smaller, *restricted* “gold bubble” / corona dynamics

Why was the HFM *not* the model of choice going into the first NIC energetics campaign?

- Desire to be conservative re: drive
  - 2-D model said it was only a 5-10% effect in drive for ignition hohlraums
  - High drive result for empty hohlraums was being carefully evaluated – very first campaign of full NIF
- f=0.15 needed for Omega Au spheres- but was it relevant for hohlraums?
  - f=0.05 used most often for smaller scale experiments
  - Non local packages implied f=0.15, but were not robust at that time
- Lack of appreciation of the interplay of f=0.15 and DCA to cool the hohlraum plasma
  - Cooler and dielectronic make for more active bound electrons, which cool even more
- In retrospect- by *not* adopting the HFM, we were *not* being conservative vis a vis LPI
  - And it was LPI that provided the inspired guess re: T, that was the ‘tipping point” for adapting the HFM for NIC ignition hohlraums

Coupling: A 3-D insight (and an inspired guess) changed our thinking about SRS

Coupling: Color of Raman light: λ_{SRS} vs. time



R_{SRS} = f (L I n / T)

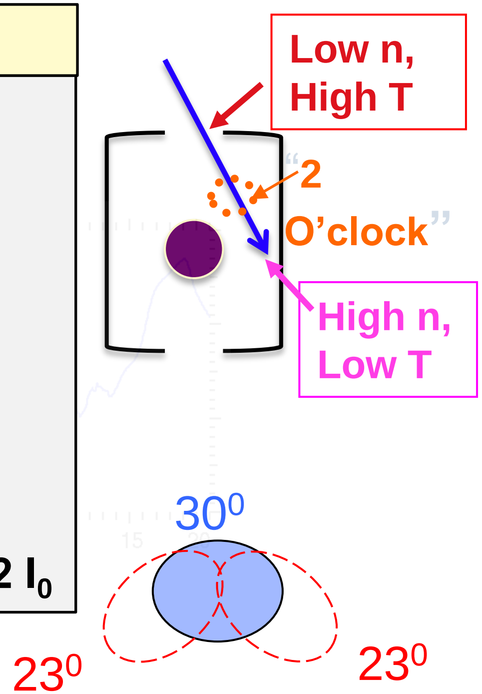
Old: I = I_0 = const: So R_{SRS} peaks at hohlraum waist

3-D Insight: (Hinkel & Williams)

At LEH: 1 30^0 & 2 23^0 beams overlap azimuthally: I = $3I_0$

At waist: The 3 beams have separated azimuthally : I = I_0

R_{SRS} peaks at "2 O'clock": I = 2 I_0



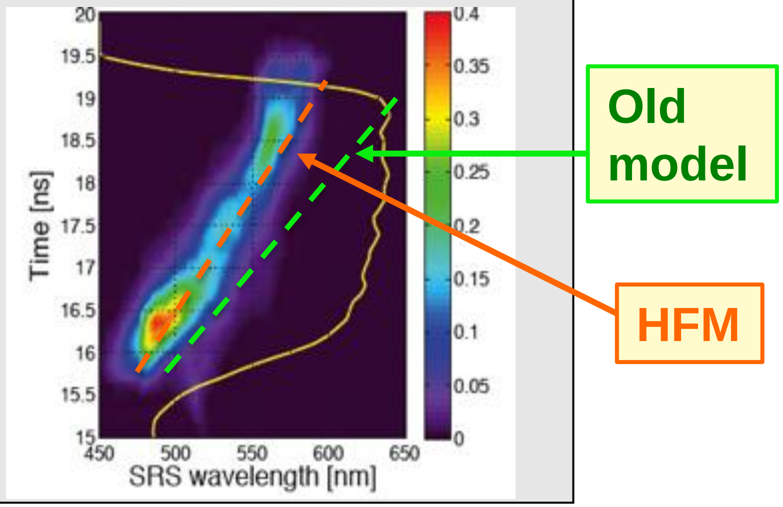
The Predicted SRS spectrum from this lower electron density (at 2 O'clock) came closer to the data.

<u>But they needed an inspired "guess" that T was lower than predicted</u>

HFM 's lower T was just what they had "guessed"

Coupling: HFM explains SRS color (vs. time) and its level (See D. Hinkel talk for the details…)

Coupling: Color of Raman light: λ_{SRS} vs. time



Intensity Level of SRS

HFM's cooler plasma leads to the ~ observed higher levels of SRS

-due to less Landau Damping

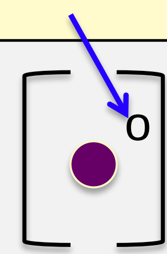
-Massive pf3D simulations are in progress (Hinkel, Williams et al)

What changed?

The plasma T_e:

Old Model T_e: 4.4 keV

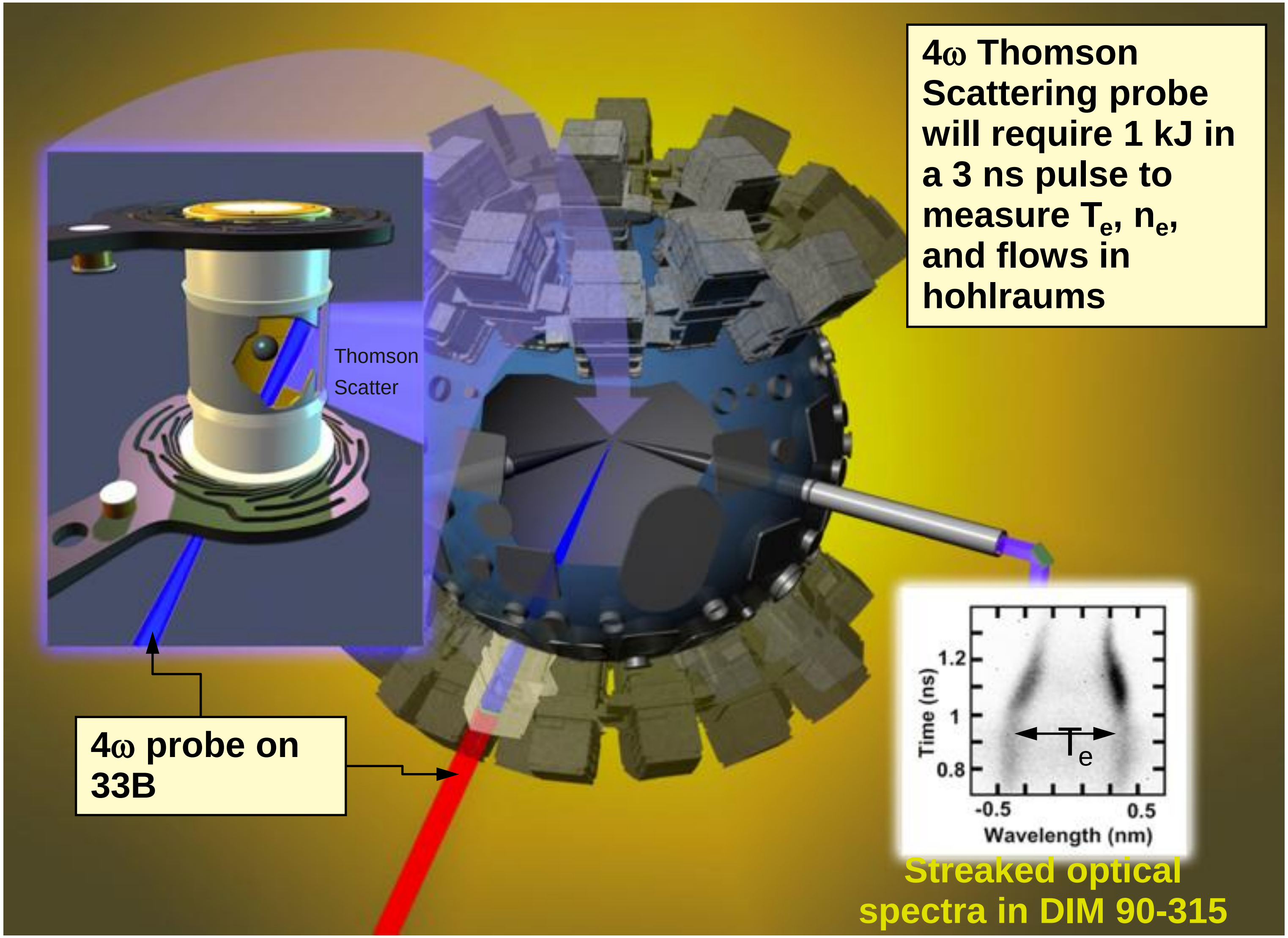
HFM T_e: 2.6 keV



(1 MJ shot, at SRS site, at 0.1 n_{crit}, at 19 ns)

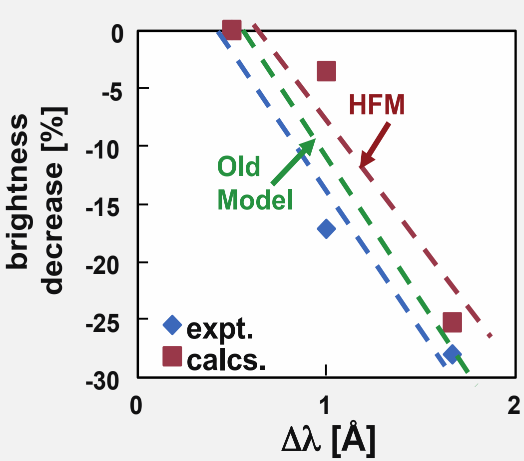
HFM's cooler hohlraum plasma is key to matching the SRS spectrum and to the observed higher levels of SRS

Thomson scattering with a 4w probe laser will be an important diagnostic for ignition hohlraums and basic science



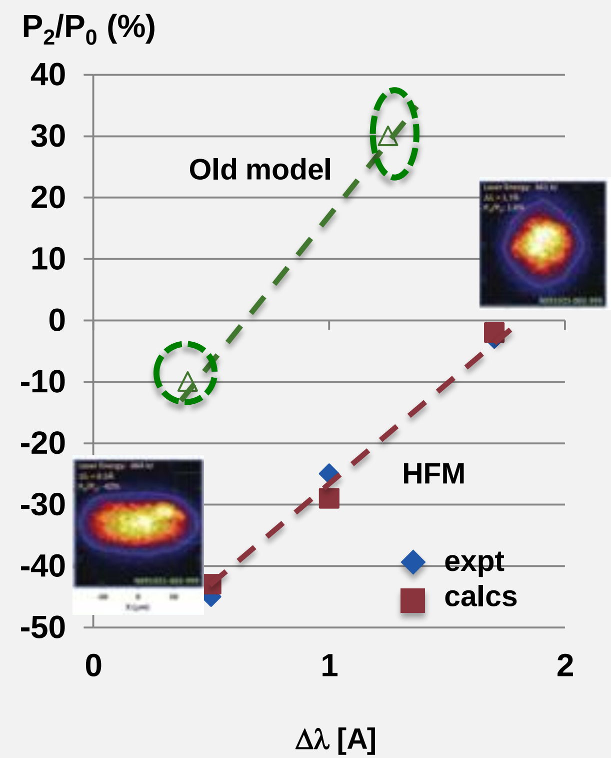
Symmetry: Our cross-beam-transfer model, coupled to the HFM agrees with data (P. Michelle, R. Town et al)

Cross-Beam Transfer



In both models, old & HFM, outer beams lose x-ray brightness due to transfer

But only HFM matches Symmetry



What changed ?

HFM more pan-caked:

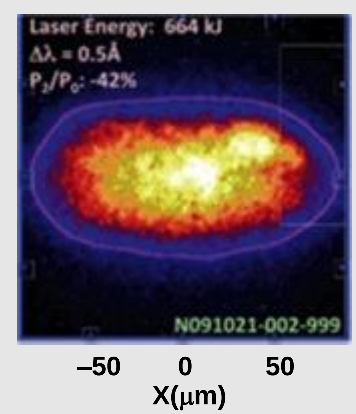
-Outer beams convert laser energy to x-rays better:

They shine on poles

-Inner beams have difficulty propagating, through the cooler plasma

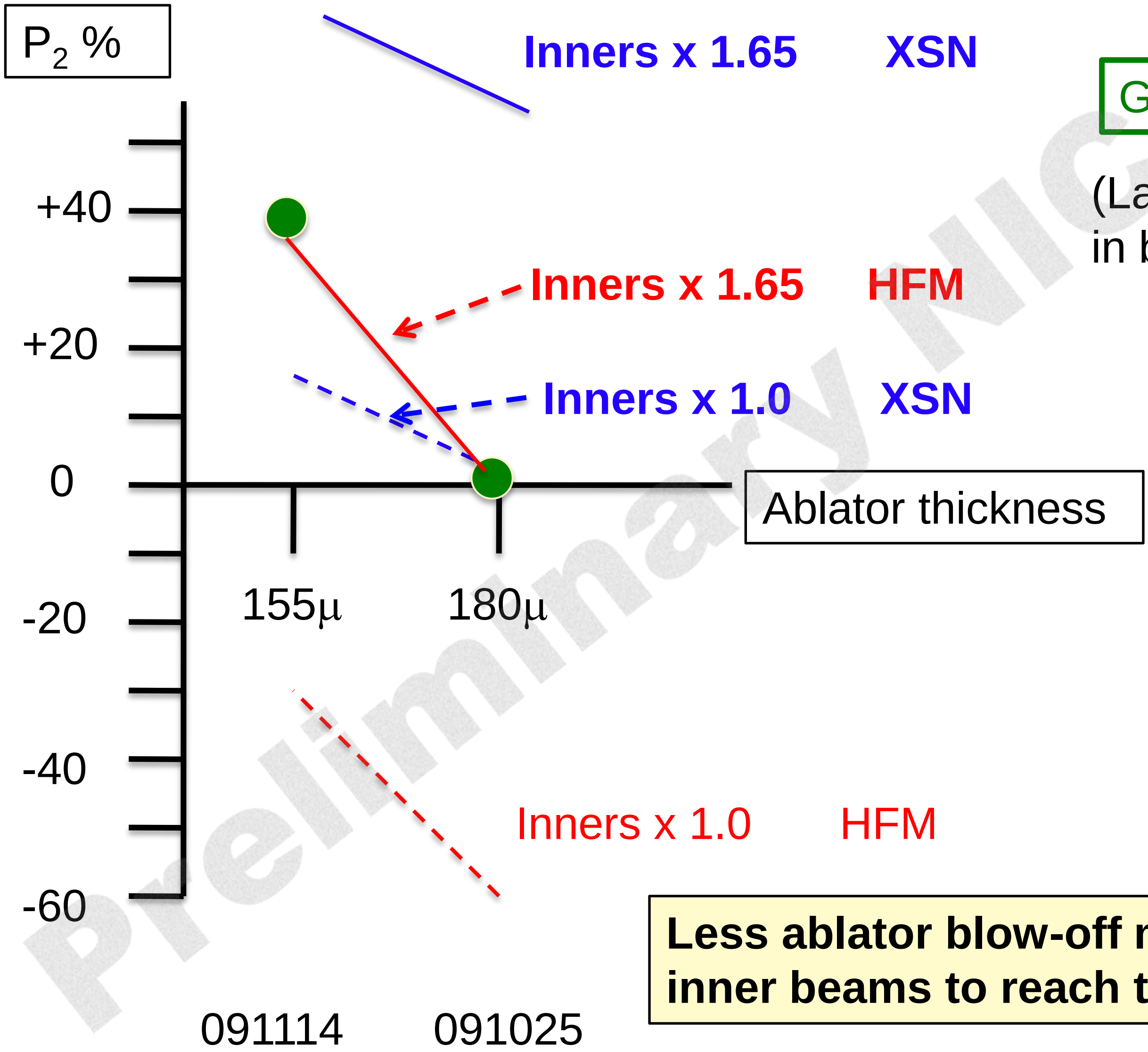
Can't get to equator

Symmetry: Why was the implosion pancaked prior to the Δλ symmetry tune?



HFM's cooler plasma and higher coronal flux key to pan-caked symmetry behavior

HFM's symmetry behavior vs. ablator thickness better than that of XSN



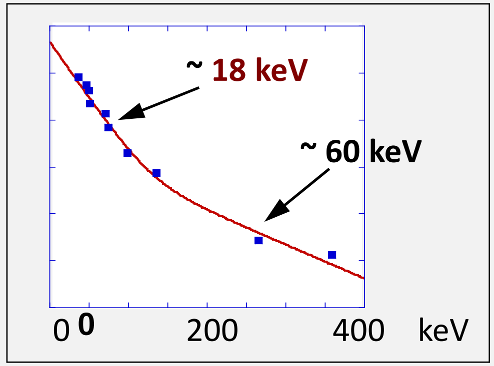
(Large $\Delta\lambda$ used in both shots)

Less ablator blow-off makes it easier for inner beams to reach the hohlraum's waist

Drive: The HFM + Re-evaluating SRS & Debris Shield losses have helped "balance the energy books"

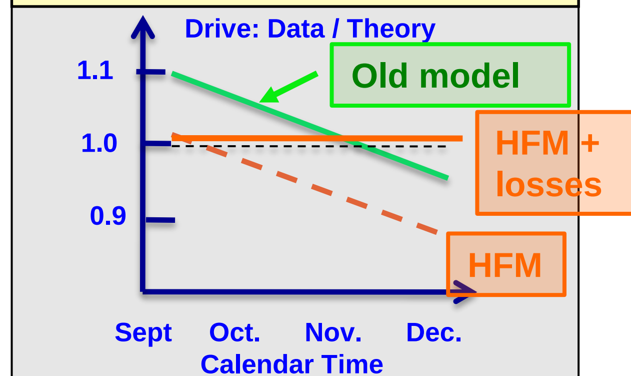
Re-evaluated losses

1) Disposable Debris Shield (DDS) aging
   (C. Haynam et al)
   ~ 5% scattering losses in Nov-Dec shots
2) Hard x-ray spectrum re-interpreted as "2 – T_{hot}"s
   (P. Michel, L. Divol et al)



From $f_{18\ keV}$ get $SRS_{total\text{-}new}$: > SRS_{old}

Drive: Energy accounting was off: Surplus in Sept., and a Deficit in Dec.

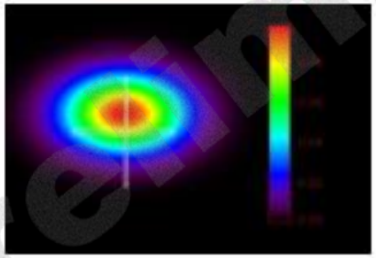


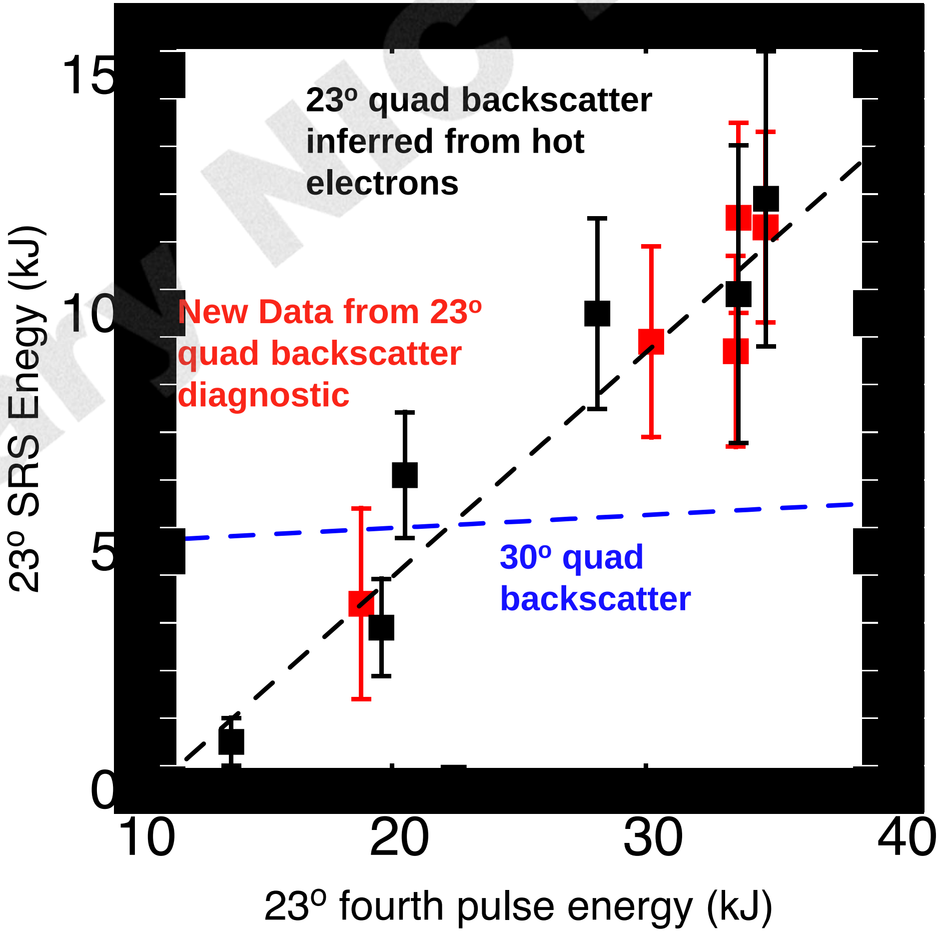
What changed?

HFM's high flux solves "surplus"

Re-evaluation of optical and SRS losses solves "deficit"

Our new 23º quad backscatter diagnostic confirms the backscatter inference based on hot-electrons

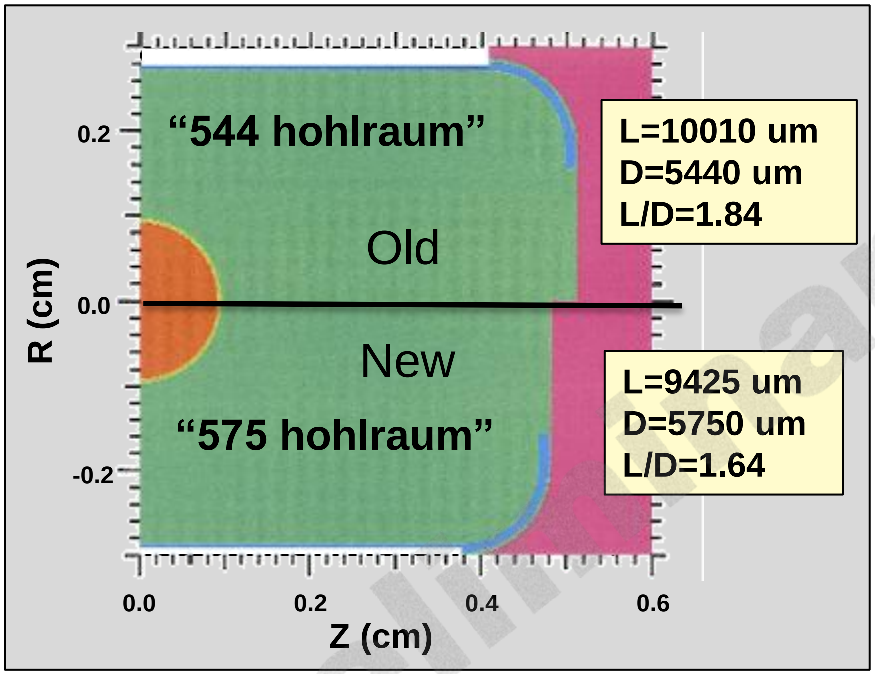




[1] see J. D. Moody talk in GO5 for more details

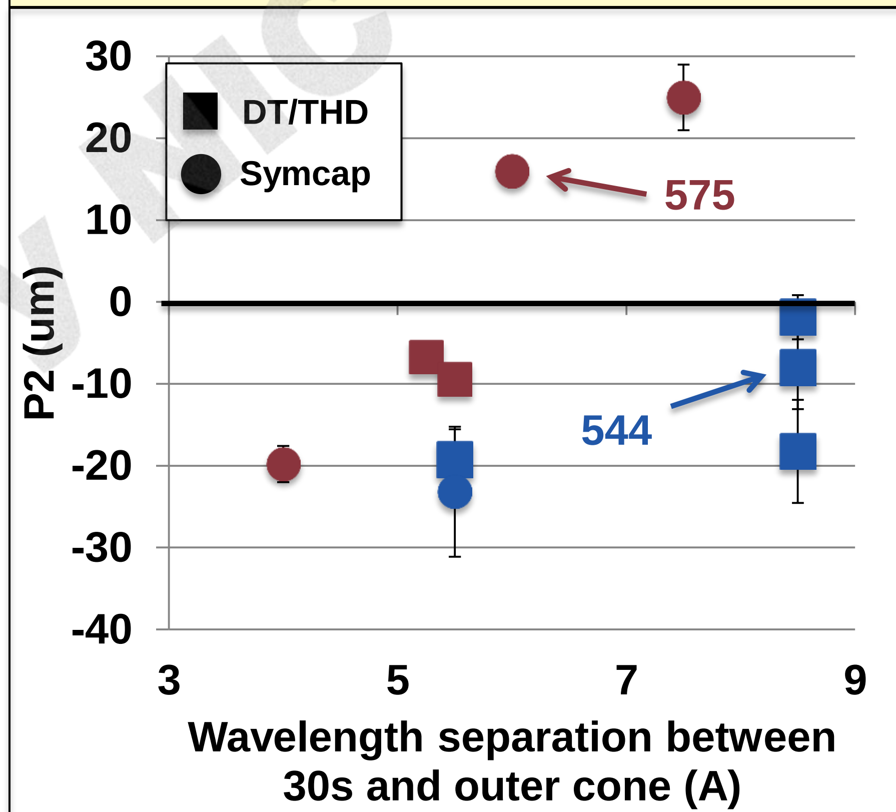
New hohlraum geometry allows us to tune P2 to round with available wavelength separation

Hohlraum aspect ratio was changed based on HFM



The "575" allows for better inner beam propagation, & its pole sees larger Ω_{LEH}

After shocktiming, all implosions in 544 hohlraums had P2 < 0



New "575" hohlraum, with its L/D "Golden Ratio", allows us to tune P2


NIC